Performance evaluation of a small and decentralized recycling unit as an alternative for construction and demolition waste valorization

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Abstract: This work evaluated the environmental and operational performance of a full-scale small and decentralized construction and demolition waste (C&DW) recycling unit (SDRU) as an alternative for its valorization. The SDRU was defined as having a production capacity of up to five cubic meters per hour, occupying up to 100 m^2. The operational and environmental performance indicators of the SDRU were obtained in the literature and validated by expert judgment. Subsequently, the values of these indicators were obtained in a SRDU implanted in the city of *Feira de Santana*, *Bahia* state, Brazil. The results showed that the SDRU presented lower levels of noise emission, very small water and energy consumption and inhalable particles concentration values lower than the requirements of Brazilian environmental legislation. It was observed that 90% of the C&DW on the storage area have recycling potential due to the high level of segregation at the construction site. The SRDU Lyfe Cycle Assesment was also applied and it was concluded that the use of the recycled aggregate for manufacturing concrete without structural function resulted in a decrease of environmental impacts in all the categories considered due to the impact of natural sand and gravel extraction from nature. The characteristics of the fine recycled aggregate is suitable for use in road or sidewalk paving and the coarse recycled aggregate; for use in concrete without structural function. The performance of the recycling unit can be optimized with small adjustments and investments mainly in comminution and C&DW transportation from storage bays to SRDU.
Keywords: construction waste, demolition waste, indicators, recycling aggregate, valorization

1. Introduction

The most recent report published by the Brazilian Institute of Geography and Statistics show that the Brazilian housing shortage reached 7.7 million dwellings in the year of 2015 [1]. This dramatic situation has been dealt with the implementation of governmental policies and investments in the construction of houses and apartment buildings, which the structure is mainly composed of structural walls. This type of building structure is especially attractive for the valorization of the construction and demolition waste (C&DW) and researches show that 90% of the Brazilian C&DW are composed by concrete blocks, bricks and tiles.

Considering the Brazilian territory, it was estimated an annual C&DW generation of approximately 38 million cubic meters (calculations considering specific mass of 1,200 $kg.m^{-3}$) at the end of 2016. The Brazilian Sanitation Information System reports that the information regarding the flow of C&DW in the year of 2016 is lacking and precarious, but reports show that 690,000 m^3 were sent for recycling, which represents only 2% of the estimated C&DW generation.

In Brazil, the C&DW management guidelines are defined by the National Solid Waste Policy, Law 12305/2010 and the Resolution 307/2002 published by the National Environmental Council [2-3]. These regulations stipulate that municipalities must have a C&DW management plan and also provide the facilities to collect and recover the waste produced by small generators that produce between 1.0 and 3.0 m^3 per day. The Brazilian big waste generators are responsible for the management and final destination of the C&DW produced in their own industries or companies. The low percentage of recycling in Brazil indicates that both small and big generators dispose of their waste inappropriately, causing severe environmental impacts.

According to Brazilian Technical Standards [4], C&DW are classified according to their potential use or destination. CD&W class A consists of mortar, concrete and ceramic materials and they have the potential to be recycled and reused in many different ways during construction of buildings, roads and sidewalks, for example.

Most of the recycling facilities in Brazil had a nominal processing capacity of between 5,000 and 10,000 cubic meters of aggregates per month using crushing equipment with nominal capacity of 25 to 50 cubic meters per hour [1]. The big processing facilities are the most used in Brazil and only 20% are of the mobile type with a production capacity of up to 100 tons per hour [3]. The mobile and small units are not generally used and some barriers need to be overcome to enable its large-scale implementation. During informal and preliminary investigations (data not shown), we find some strongly held opinions that these units produce poor quality aggregates, and can generate unacceptable levels of noise and dust for nearby residential areas. The lower implementation cost of these units may not compensate for their low productivity and the unattractive selling prices of the recycled aggregate.

The implementation of these small and mobile recycling units in Brazil by public entities or private investors still faces many challenges and uncertainties such as: the environmental regulation for C&DW management, the perception of different professionals, economic aspects (costs and benefits) and excessive bureaucracy. In addition, most of the studies published in the literature on C&DW recycling

units and their performance apply to medium and large ones, which have more than one processing stage and use robust equipment occupying large areas.
Therefore, considering the gap of technical information, this paper aims to select indicators of environmental and operational performance suitable for smaller and decentralized C&DW recycling units and get their values in a full-scale site. The characterization of C&DW and recycled aggregates was also carried out in order to identify opportunities for the reinsertion of these materials in the production cycles and to reduce construction costs.
The mobile, small scale and decentralized recycling unit (SDRU) in this paper was defined as having a production capacity of up to five cubic meters per hour, occupying up to 100 m². The equipments and devices used are transportable with an easy operation and require only one employee to keep it running. Thus, it was also adopted the premise that this option is, in essence, a decentralized alternative of C&DW valorization, being possible its installation close to the source of generation, and also in reception points of small volumes of C&DW. Therefore, the possibilities are extended since other agents of the C&DW technical network may be involved, such as the small generator.

2. Material and Methods

2.1 Description of the SDRU

The SRDU is located in a construction site in the city of *Feira de Santana*, *Bahia* state, Brazil (-12.264492S and -38.925995W). The C&DW generation source was a construction of twenty low-income apartment buildings occupying a total area of 36,511.19 square meters. The constructing method adopted was the structural masonry with precast slab. Table 1 shows the main characteristics of the SDRU installed on the construction site and of the equipment (*Queixada 200P*) used to grind the C&DW.

Table 1. Main characteristics of the SDRU and of the crushing equipment (*Queixada 200P*)

Description	Characteristics
Effective Area	85 m²
Dimensions of the C&DW storage bay	6.2 x 3.8 x 1.7 meters
Dimensions of fine recycled aggregate storage bay	4.0 x 4.1 x 1.7 meters
Dimensions of coarse recycled aggregate storage bay	4.0 x 3.7 x 1.7 meters
Dimensions of the ramp for manual transport of C&DW	3.8m (length):1.0 m (high)
Height of the equipment considering the device for collecting the aggregate	1.4 m
Nominal capacity	1.1 cubic meters per hour
Energy consumption	3.0 kilowatts per hour

The C&DW class A (mortar and concrete) segregated at the construction site was transported using mini backhoe or wheelbarrow up to the storage bay. If necessary, this C&DW was manually comminuted, since the crusher (*Queixada 200p*) has an inlet with a 15 x 20 cm opening. After this stage, the CD&W was transported by wheelbarrow to the crushing equipment. The *Queixada 200p* is equipped with a set of sieves separating the coarse from the fine recycled aggregate that were stored in specific bays. The Figure 1 shows the C&DW class A storage bay and an access ramp for transporting C&DW.

Fig.1 Small and decentralized recycling unit (SRDU) site in *Bahia* state, Brazil

2.2 Indicators of environmental and operational performance

The selection of the environmental and operational performance indicators was conducted in two sequential and complementary steps. Initially, a review of the literature was performed considering the following criteria: (i) coherence with the object of study, (ii) technological, economical and temporal feasibility to measure the performance of the SDRU, (iii) elaborated from primary data, (iv) data or information from a reliable source. Yuan and Shen [5] stated that literature review is generally considered as a key methodology for examining the development trend of research in a particular discipline. However, indicators should be chosen according to well-established scientific criteria and the validation step is imperative. Therefore, following the recommendations proposed by Bockstaller and Girardin [6] the end use validation based on specialist judgment was applied in our study.

The total of 115 indicators of C&DW recycling units performance were identified in the literature. From these, 48 referred to environmental aspects and 38 to operational performance. Most of these indicators are used for fixed units with capacity above 100 tons per hour. We also identified 29 financial performance indicators that will not be addressed in this paper. At first, those indicators that were similar or that did not fit the characteristics of a SDRU were excluded.

The ones chosen after that stage were submitted to the judgment of 13 experienced professionals members of the National Research Network entitled: Methodologies and Technologies for the Sustainable Management of Solid Waste: Emphasis on the Reduction and Valorization in Urban Environment – TECRESOL. These professionals answered the following question: Does this indicator allow evaluating the environmental, financial or operational performance of a decentralized and small C&DW recycling unit? The answer was objective (yes/no) however; there was the possibility of including comments or suggestions. The performance indicators that obtained 50% of approval were considered relevant after the validation step.

After the validation step, we collected primary and secondary data during nine consecutive months by daily monitoring of the SRDU at the construction site located in the city of *Feira de Santana*, *Bahia* state, Brazil (-12.264492S and -38.925995W). The feasibility of obtaining data was analyzed regarding the availability, purpose, costs and adherence to the characteristics of the SRDU. After this evaluation, 4 environmental performance indicators and 13 operational performance indicators were maintained (Table 2). The environmental performance indicators represent the consumption of natural resources and energy, the generation of emissions of noise and particulate matter. Meanwhile, operational performance indicators represent productivity, inputs and outputs, worker training and safety, and physical structure.

Table 2. Indicators selected for environmental and operational performance evaluation of the SDRU

Environmental performance	
Indicator	**Description**
Noise emission	Measurement of sound volume (decibels).
Emission of particulate	Mass of pollutant by volume of air ($\mu g.m^{-3}$) measured during the production of recycled aggregate.
Water consumption	Volume consumed per volume of recycled aggregate ($L.m^{-3}$).
Energy consumption	Ratio between the SDRU's energy consumption and the total energy consumption of the construction site.
Operational Performance	
Indicator	**Description**
Maximum storage time of coarse recycled aggregate	Ratio between the volume of the storage bay and the coarse aggregate flow rate (m^3 per day).
Maximum storage time of fine recycled aggregate	Ratio between the volume of the storage bay and the fine aggregate flow rate (m^3 per day).
Percentage of the time spent for comminution	Ratio between the comminution time of the C&DW class A and the total crushing time (dimensionless).
Feeding time of the crusher[a]	Time spent to transport C&DW class A between the storage bays and the crusher feeding device (hour).
Flow rate of C&DW crushed	Ratio of the C&DW class A volume recycled and crusher operation effective time (m^3 per hour).
Percentage of coarse or fine recycled aggregate obtained	Ratio between the volume of coarse or fine aggregate and the total volume of recycled aggregate produced in the crusher (dimensionless). We suggested obtaining this indicator always at the end of the working day.
Losses during the crushing process[b]	The complement of the ratio between the sum of volumes of coarse and fine recycled aggregates and the volume of C&DW (dimensionless). We suggested obtaining this indicator always at the

	end of the working day.
Idleness of crushing equipment in a working day	Total time of interruption of the operation of the crushing equipment (hours). Obtained by the multiplication of the number of interruptions by the duration of time of each of these interruptions. We suggested obtaining this indicator always at the end of the working day.
Total production time in a working day	It is the effective production time (hours). Obtained by the ratio between the sum of the times spent with comminution, transportation, crushing, cleaning of the equipment and organization of bays and the time of one working day.
Training time	Time expended for training the SDRU workers (hours). Obtain at the end of a month of SRDU operation.
Quality of raw material	Ratio between the volume of the C&DW class A and the total volume of the C&DW discarded in the SDRU (dimensionless).
Existence of vibration control mechanism requirement for worker safety	Yes or no
Protection of raw material to ensure crushing conditions. Requirement to avoid rainfall over C&DW	Yes or no

a - The following should be taken into account: time to transport the C&DW class A from the waste bays to the crusher, time of crushing operation, time to transport recycled aggregate from the crusher to recycled aggregate storage bays and the time of clearing the sieve and organization of storage bays.
b - $Losses = 1 - \frac{V_1 + V_2}{V_t}$;
V_1 – Volume of fine recycled aggregate
V_2 – Volume of coarse recycled aggregate
V_t - Volume of C&DW

The environmental impacts related to SDRU operation were also estimated using the Life Cycle Analysis (LCA) approach. We considered that the recycled aggregate was used for the production of concrete without structural function. A comparison was made between the production of concrete 20 MPa without structural function manually made from natural sand, gravel, cement and water, and the production of the same type of concrete replacing the sand by fine recycled aggregate and the gravel by coarse recycled aggregate. The LCA boundaries include the production of concrete with its inputs and the recycling of C&DW class A using the *Queixada 200P* model equipment. During the elaboration of the LCI, the C&DW class A, the energy consumption of the equipment and the output of the emitted particulate material and the fine or coarse recycled aggregate were considered as input. The study covered only the phase of operation of the recycling equipment. In our work, the LCA was carried out using *SimaPro®* 8.0.1 PhD version.

2.3 Obtaining indicators and characterization of C&DW and the recycled aggregate

The C&DW class A discarded in the storage area of the SDRU was characterized by visual observation and laboratory analyzes following the recommendations and procedures published by the Brazilian Technical Standards [7-13]. The gravimetric composition and grain-size distribution were determined and the unit mass (loose state) of the C&DW was obtained by the examination of three duplicate aliquots from three different samplings. The fine and coarse recycled aggregates produced were characterized in order to indicate the possibility of its use for the production of concrete without structural function or road and sidewalk paving. A composite sample was obtained by collecting 18 (eighteen) aliquots with 10 (ten) kg of the top, middle and bottom of each piles of recycled aggregate stocked at the storage bay.
The noise level emitted by the recycling equipment was measured using the method proposed by the Brazilian Technical Standards [14]. Four points were selected in the SDRU, with the following locations: point A was located 1.5m from the recycling equipment, the point closest to the sound source; point B was located in the storage area of C&DW, in which the operator was working; point C was at a distance of 4.2m from the sound source and at a distance of 2m from the site boundary and point D was at a distance of 2.0m from the residences near the construction site.
The emission levels of particulate matter were measured by a *Berner* impactor with a six-stage impaction sampler with different aperture diameters. At each stage, particulate material compatible with the aperture of the equipment is retained in the membrane filters, which are weighed before and after the samplings *in*

loco to determine the amount of particulate material. Four samplings were performed, three of them with the recycling equipment in operation and one with the equipment turned off.
The Brazilian Environmental Council [15] uses the 24-hour period to establish concentration limits for Total Suspended Particles (TSP) and Inhalable Particles or Particulate Matter of up to 10µm (PM10). For the primary air quality, the TSP 24-hour average concentration limit of 240 $\mu g/m^3$ of air is established, which can be exceeded only once per year. It is considered a primary standard the amount of pollutant that if exceeded, may affect the health of the population. For PM10, it is accepted the maximum value of 24-hours average concentration equal to 150 $\mu g.m^{-3}$ of air that can also be surpassed only once a year.

3. Results and discussion

3.1 SDRU environmental performance

Based on the values measured at each point, it was possible to verify that at the Point A which was close to the crushing equipment, the highest levels of sound pressure were detected, an average of 81.6 dB. According to the Brazilian legislation [16], this value is higher than the acceptable level of 55 dB for the daytime period in mixed areas, predominantly residential as the area investigated.
During the operation of the SDRU there was the emission of TSP and PM10 during the recycling process. Particles with a diameter between 14.9 and 4.9 µm predominated in most samples. The highest value during the recycling process lasting six hours per day of particulate material sampling was 1,439 $\mu g.m^{-3}$, and the TSP of 1,460 $\mu m.m^{-3}$. These values suggest that care should be taken to reduce the operator's exposure to particulate matter, since particles smaller than 10 µm represent a risk factor for the development and worsening of cardiovascular and respiratory diseases [16].
In the study area there was no water supply, and therefore its consumption was zero. The energy consumed by the crushing equipment (*Queixada 200p*) was provided by a diesel generator. Table 3 shows some of the values of environmental indicators obtained for SDRU located at *Feira de Santana* city, *Bahia* state, Brazil.

Table 3. Values of the Indicators selected for environmental performance evaluation of the SDRU

Indicator	**Results**
Noise emission	81.6 dB [(a)]
Emission of particulate matter	TSP =1,460 $\mu g.m^{-3}$ ([b)]
Water consumption	0
Energy consumption[c]	0.16 to 0.62 (%)

Notes: (a) point A is the closest to the equipment. (b) The results refer to a single sampling with three aliquots, taken for six hours. The highest observed value is shown. (c) The value represents the consumption of the SRDU considered as a part of the total energy consumption of the site.

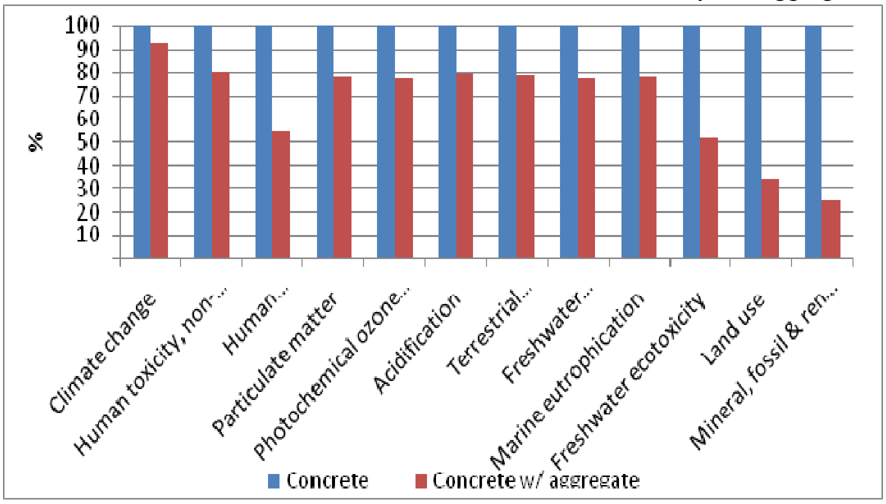
During the C&DW recycling process, we obtained an operational performance indicator of losses of 8%. It is possible to say that from 100 kg of C&DW that enters in the equipment, 92 kg is recovered as recycled aggregates, of which 60% corresponds to coarse aggregate and 40% to fine. The total time of equipment operation was of 86.9 hours and, as it is known that the equipment consumed 3 kilowatts per hour, it was possible to calculate the total energy consumption during the period. These values were considered to draw up the Life Cycle Inventory (LCI) of the recycled aggregate production in the crushing equipment (Table 4).

Table 4. SRDU's Life Cycle Inventory

Output	**Total**
Fine recycled aggregate	97,539.2 kg
Coarse Recycled Aggregate	144,931.8 kg
Emissions to air	
Particulates	52.7 mg
Input (electricity)	
Electricity, low voltage	260.8 kW

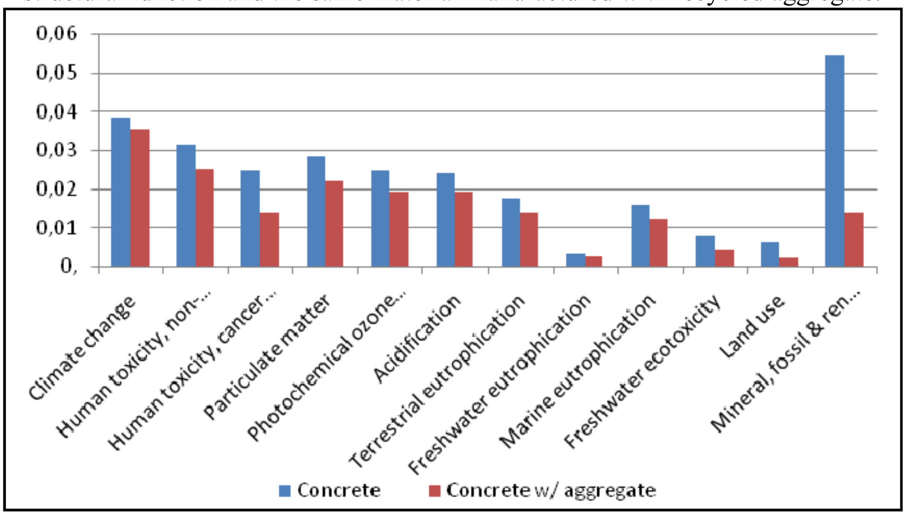
The results are applicable only for the considerations and assumptions made for this LCA study. The comparison's result of the production of 1.0 m^3 concrete without structural function, using the ILCD 2011 Midpoint V1.07 / EU27 2010 method, is presented in Figure 2.

Fig. 2 Comparison of the Life Cycle Impact Assessment between conventional concrete without structural function and the same material manufactured with recycled aggregate



It is possible to state that there was a decrease of environmental impacts in all the categories considered. This is due to the reduction in the consumption of natural resources and energy for the extraction of natural sand and gravel, which present greater impact potential than the energy consumption and emission of particulate material from the SRDU. The categories with the greatest environmental impact potential reduction were "Land Use" and "Depletion of Mineral Resources". Considering these categories, the contribution of gravel and sand to the impact potential was greater than 60%. Therefore, using the recycled aggregate in substitution for these materials is shown to be environmentally positive. The result of normalization for the production of one cubic meter of concrete without structural function using the ILCD 2011 Midpoint V1.07 / EU27 2010 method is shown in Figure 3.

Fig. 3 Result of the standardization and comparative analysis between conventional concrete without structural function and the same material manufactured with recycled aggregate.



Considering the manufacture of conventional concrete without structural function, the results confirm that the most relevant category was the "Depletion of Mineral Resources" due to the impact of natural sand and gravel extraction from nature. Using the fine and coarse recycled aggregate, the most relevant category was "Climate Change" due to the impact of cement production. The electricity used to extract or produce construction materials such as Portland cement came from the Ecoinvent® database, which takes into account the European energy matrix based on fossil fuels. This is an important limitation of our study and should be taken into account by decision-makers. The reduction of the uncertainty of the LCA studies conducted in Brazil demands the construction of a Brazilian database. Although difficult and time-consuming, this task must be progressively accomplished. The standardization confirmed the environmental gain by using recycled aggregate rather than natural sand and gravel for the production of concrete.

3.2. Operational Performance Indicators

The values of operational performance indicators are shown in Table 5. The degree of segregation of raw material (C&DW) was very high; we have identified only 0.05% of other wastes that were not mortars and concrete. This is a crucial step in making the process attractive from the economic and financial point of view and is also a challenge, since the labor in the construction sector is very unqualified in Brazil. It should be mentioned that the SDRU installed in *Feira de Santana* city, has only one operator who has not received training for all activities.

Table 5. Values of the indicators selected for operational performance evaluation of the SDRU

Indicator	**Results**
Maximum storage time of coarse recycled aggregate	15 days
Maximum storage time of fine recycled aggregate	25 days
Percentage of the time spent for comminution	2.5%
Feeding time of the crusher	0.73h
Flow rate of C&DW crushed	0.5 a 1.1 m^3 per hour
Percentage of coarse recycled aggregate obtained	60.6%
Percentage of fine recycled aggregate obtained	39.4%
Losses during the crushing process	8%
Idleness of crushing equipment in a working day[(a)]	2.4h
Total production time in a working day[(a)]	4.3h
Training time	No training was performed
Quality of raw material	0.05%
Existence of vibration control mechanism requirement for worker safety	No
Protection of raw material to ensure crushing conditions.	No

Note: (a) 8-hour working day.

The productivity of the crusher varied between 50 and 100% of the nominal capacity. This range was due to the irregularity of the C&DW input flow. The time spent in transporting the C&DW by wheelbarrow corresponded to a high value of 17% of the total time of production. Besides, other interruptions such as the verification of the electrical installations, the need to clean the storage site of C&DW, the necessity of the operator to perform other activities outside of the SDRU contributed to the idleness of the crushing machine. It was verified that there is no vibration control mechanism recommended to give greater protection to the operator's health. Improvements such as using treadmills or a team with two operators would allow productivity gain.

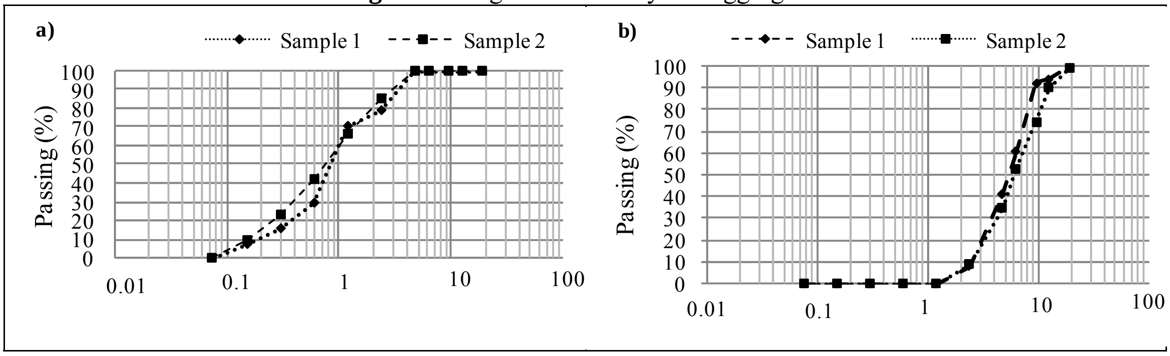
The recycled aggregates produced were destined for several purposes, such as the manufacture of concrete blocks, use in the execution of subfloor, production of concrete without structural function, among others. The use of recycled aggregates occurred in the construction site, generating savings in the acquisition of natural aggregates and minimizing the environmental impacts associated with the transport of this material.

3.3. C&DW and recycled aggregate characterization

The C&DW unit mass was equal to 978.5 ± 30.4. Only large pieces of precast concrete blocks, concrete and fine materials like sand, gravel, soil and cement were found in the C&DW aliquots collected. Preliminary classification tests showed that 40% of the C&DW presented dimensions smaller than 75 mm. Therefore, the comminution step is imperative because there is an incompatibility between the size of the C&DW and the feed device of the crusher. The low content of contamination and the small grain-size variability of the C&DW are important characteristics, since they allow the production of aggregates with greater homogeneity and uniformity.

The Brazilian Technical Standards [17-18] provides the requirements for the use of recycled aggregates in road paving and concrete without structural function, based on physical and chemical aspects such as: grain-size composition, maximum characteristic size, shape index, material that passes through 0.42 mm sieve, contaminant content, water absorption, cement and rock, California Support Index and expansibility. The Figure 4 shows the grain-size distribution curves of the evaluated aliquots.

Fig. 4 Grading curves of recycled aggregates



a) Fine aggregate; b) coarse aggregate.

The particle size distribution of the coarse recycled aggregate samples partially adapt to the 4.75 - 12.5 mm zone, which are considered the optimum dimensions for the concrete manufacturing. The samples of fine recycled aggregate were classified as average sand. The test to obtain the content of material that would pass through the sieve of 0.42 mm is required for the use of the recycled aggregate in road paving and was carried out only for the fine recycled aggregate samples. The results (24.85% and 27.93%) were considered acceptable according to the Brazilian Technical Standards [17-18].

The recycled aggregate from SRDU do not present non-mineral material contents. The specific mass varied between 2,527 and 2,550 g.cm^{-3} and maximum value of the water absorption was equal to 7.72%. These results meet the requirements for recycled aggregate used for manufacturing concrete without structural function. However, the fine recycled aggregate presented high clay content and friable materials, therefore not being suitable for this use.

On the other hand, the coarse aggregate presented values lower than 2% and there is no restriction for its application. The presence of powdery material was adequate and the average value of the shape index was 2.04, which indicates lamellar format. The content of soluble salts, chlorides and sulfates were below 1%.

The Table 6 shows a summary of the information regarding the compliance with the Brazilian Technical Standards requirements. These results show that the aggregates obtained from the SRDU have great potential for use and valorization. Regarding the clay content found in the samples of fine aggregates, the possibility of contamination during the storage of the material cannot be disregarded.

Table 6. Summary of the characterization results of the recycled aggregates from SRDU

Criteria	**Fine Aggregate Sample 1**	**Fine Aggregate Sample 2**	**Coarse Aggregate Sample 1**	**Coarse Aggregate Sample 2**	**Brazilian Technical Standards**		**Reference**
					Paving (roads, sidewalks, among others)	Concrete without structural function	
Material that passes through 0.42 mm sieve	ok	ok	n.a.	n.a.	10 – 40%	n.a	[18]
Mass of non-mineral materials (organics including plastics, wood, gypsum, glass, among others)	ok	ok	ok	ok	≤ 3%	≤ 2%	[18]
Water absorption*	ok	ok	ok	ok	n.a.	≤ 7%	[18]
Maximum characteristic size	ok	ok	ok	ok	≤ 63mm	n.a.	[18]
Powdery material	ok	ok	ok	ok	n.a.	≤ 10%	[18]
Shape Index	n.a.	n.a.	not ok	not ok	≤ 3.0	≤ 3.0	[17-18]
Clay and friable materials	ok	ok	ok	ok	n.a.	≤ 2%	[17]
Salts, chlorides and sulphates.	ok	ok	n.a.	n.a.	n.a.	≤ 1%	[17]
California Suport Index**	ok	ok	not ok	not ok	≥ 20%	n.a.	[18]
Expansibility**	ok	ok	not ok	not ok	≤ 1.0%	n.a.	[18]

Note: n.a.: not applicable; *Fine recycled aggregate (water absorption ≤ 12%); **Requirements for use as road sub-base.

4. Conclusions

Most of the environmental, economic or operational performance indicators of C&DW recycling units have been defined and obtained for facilities with a capacity exceeding 100 tons per hour. A critical review of the literature validated by the judgment of specialists allowed concluding that out of a total of 115 indicators; only 17 are applied to small and decentralized C&DW recycling facilities.

The monitoring of the C&DW recycling process for nine consecutive months applying the selected indicators allows us to verify that the emission of particulate matter is one of the critical points. Some control measures need to be taken to ensure the safety of the operators of these small and decentralized C&DW recycling units in order to avoid risk factor for the development of cardiovascular and respiratory diseases.

Applying the Lyfe Cycle Assesment approach, it was concluded that the use of the recycled aggregate in the manufacture of concrete without structural function resulted in a decrease of environmental impacts in all the categories considered. The most relevant category was the “Depletion of Mineral Resources” due to the impact of natural sand and gravel extraction from nature.

The coarse aggregate samples analyzed met the requirements of Brazilian Technical Standards for manufacturing concrete without structural function, even though they did not present optimal characteristics. The results allow to state that the recycled aggregates obtained from the SRDU have great potential for use and valorization.

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